

Electrified future of aviation: batteries or fuel cells?

Grigorii Soloveichik,
Program Director

March 13, 2018



Credit: NASA

Electrified future of aviation

- ... no more pollution
- ... no more noise
- ... less emissions
- ... more efficient use of fuel
- ... more power for auxiliaries



Electric aircraft market is projected to reach over \$22B by 2040

Aviation electrification

Benefits

- ▶ Energy usage reduction (40 - 60%)
- ▶ Emission reduction (>90%)
- ▶ Noise reduction (>65%)

Energy requirements for medium range 50 passenger planes

- ▶ Energy density >1 kWh/kg
- ▶ 4000 - 8000 kWh per hour

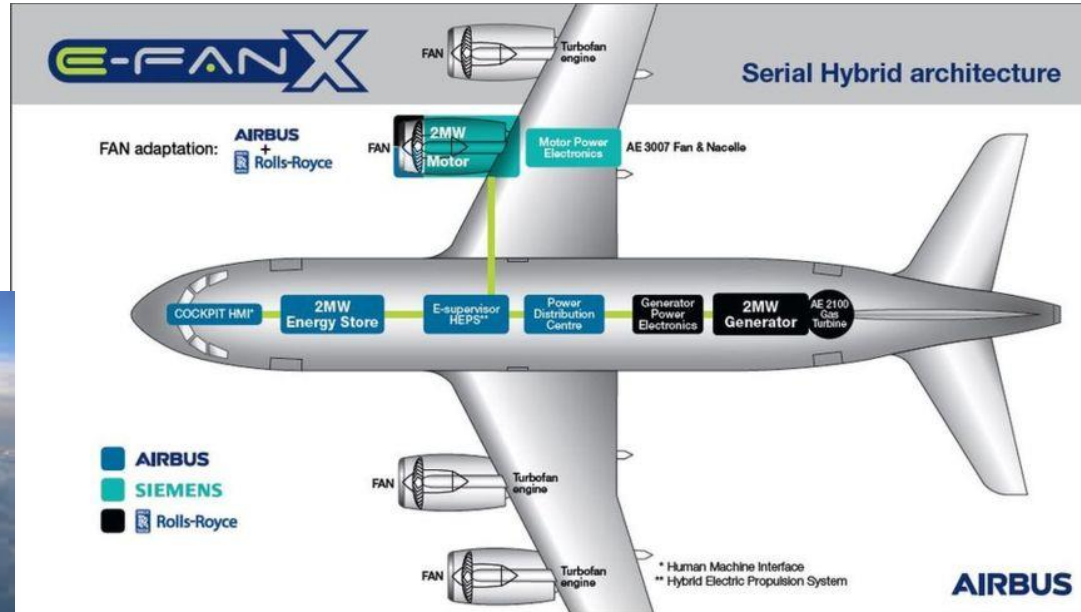
Batteries alone could support 2-4 seat short range planes...

but do not have enough energy density for regional aircrafts!

Hybrid electric aircraft concepts



Zunum Aero
50 passenger series hybrid
Range 700 miles (175 electric)



Airbus E-fan X
116 passenger series hybrid
400 kWh battery
2.5 MW electric motors



Boeing SUGAR Volt
154 passenger series hybrid
5.3 MWh battery
1.3 MW electric motors

Higher efficiency to offset higher cost

Aviation electrification: energy sources

Batteries

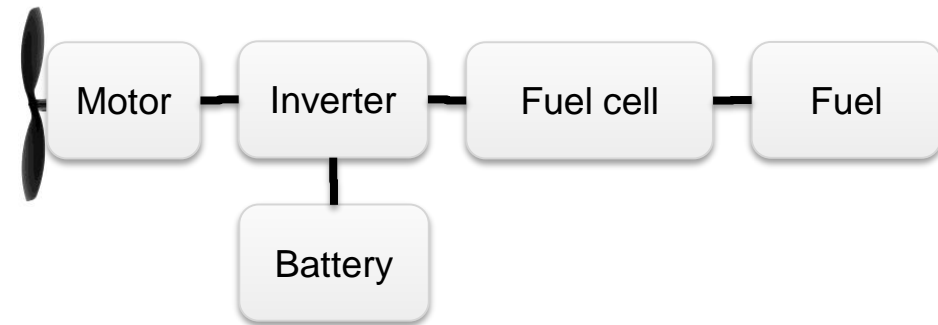
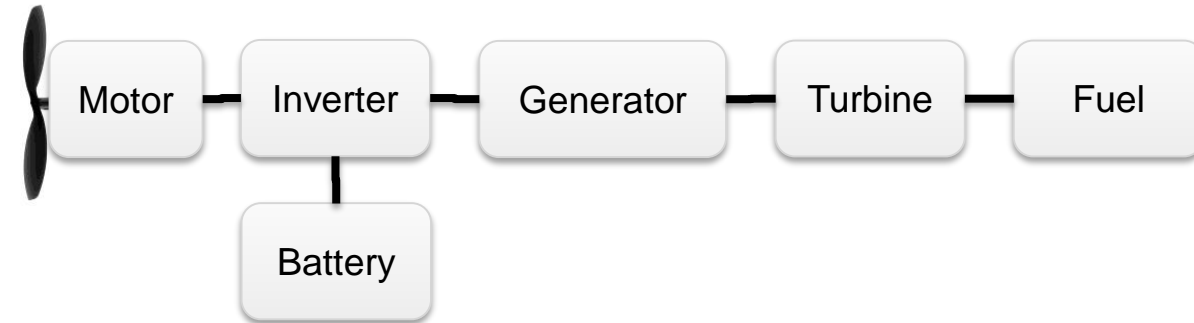
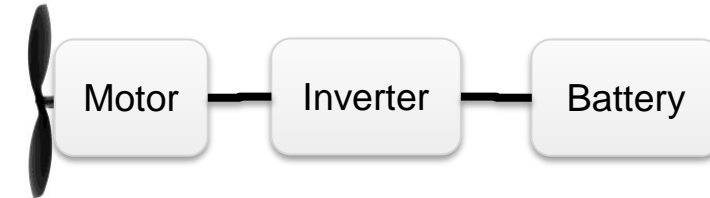
- ▶ Highest efficiency
- ▶ Energy densities above 500 Wh/kg unlikely
- ▶ Limited use for personal short range aviation

Turbines using fossil fuels + batteries

- ▶ Highest energy density but lower efficiency
- ▶ Marginal improvements in energy efficiency and emissions compared to conventional aircraft
- ▶ Need a generator and an inverter

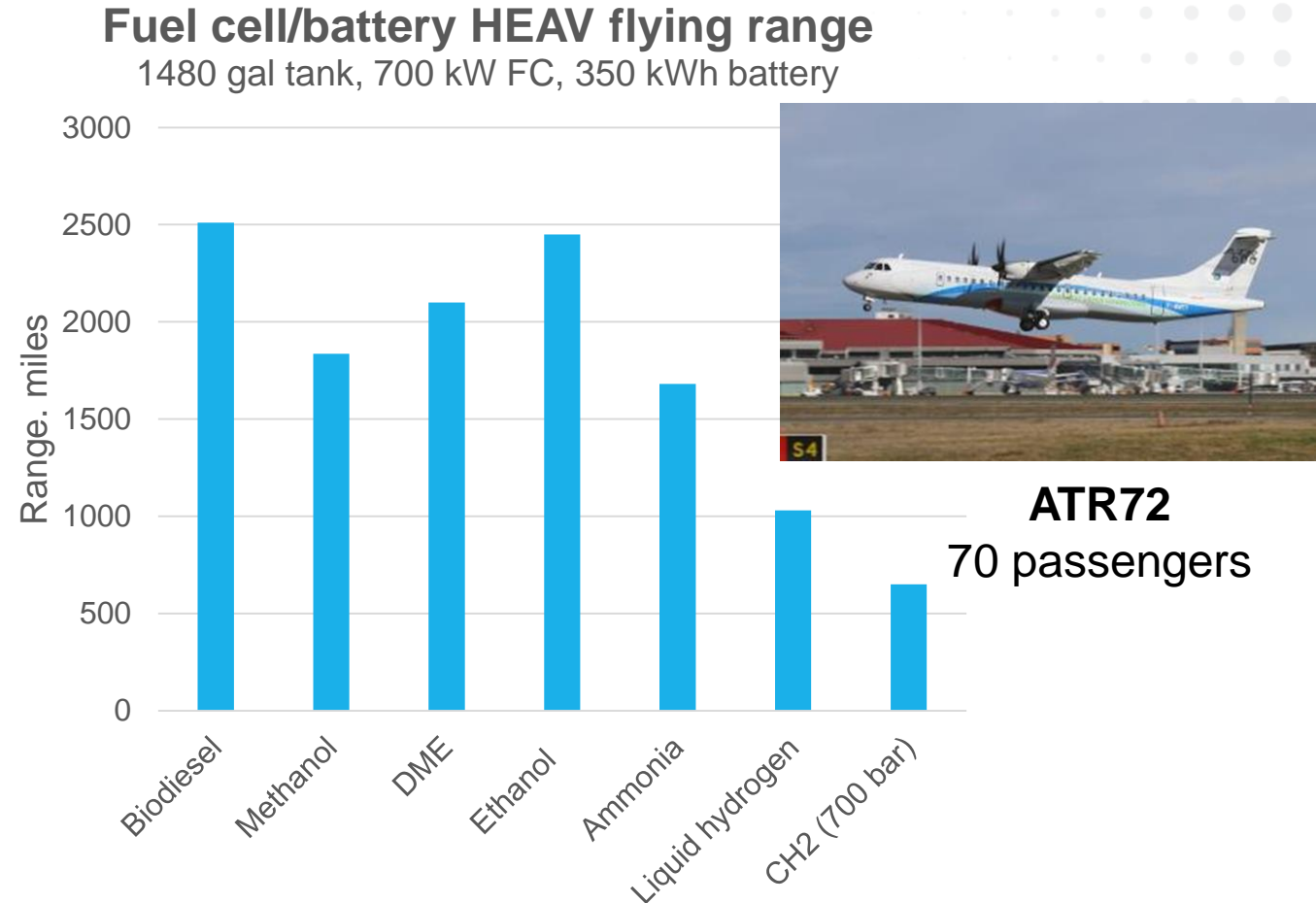
Fuel cells using sustainable fuels + batteries

- ▶ Satisfactory energy density
- ▶ Medium energy efficiency but no inverter needed
- ▶ Suitable for small - medium size passenger planes



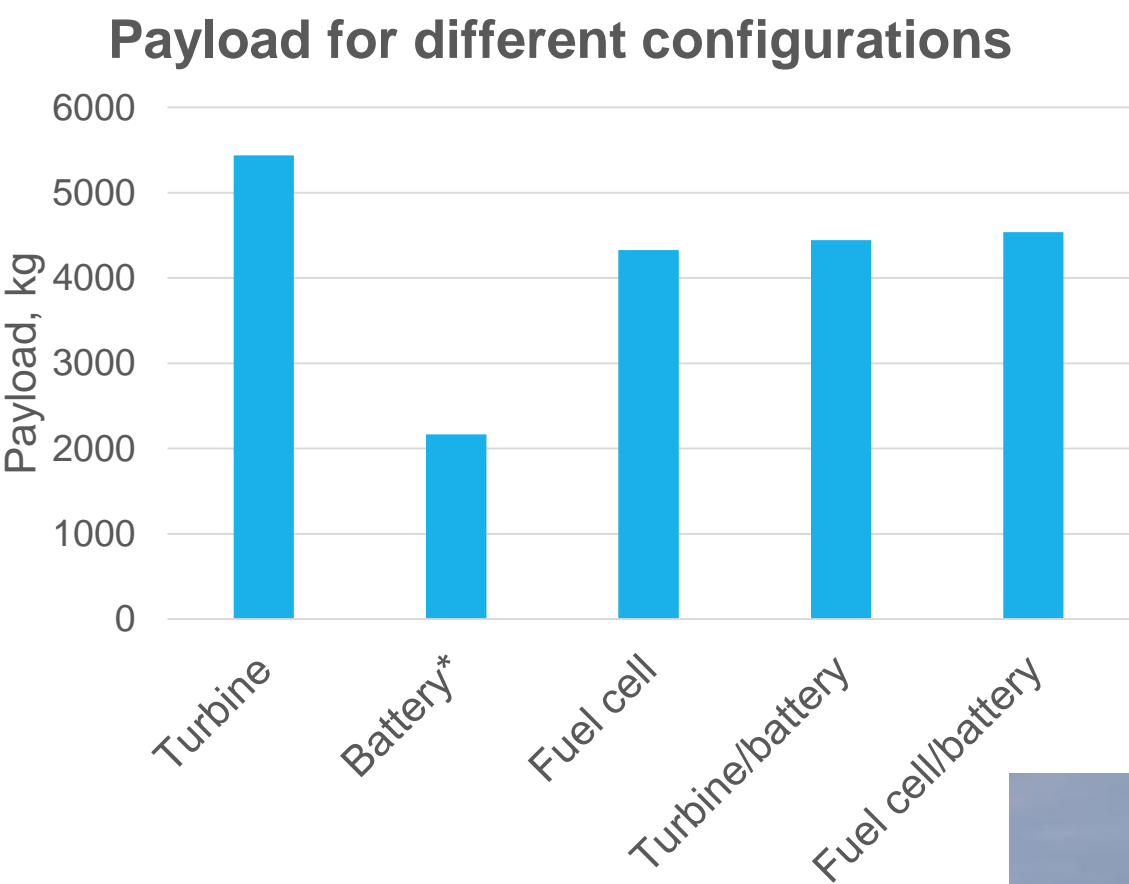
Fuels for Direct Liquid FCs

Fuel	B.p., deg C	Energy density, kWh/ L
Biodiesel	340-375	9.2
Methanol	64.7	4.67
Dimethyl ether (DME)	-24	5.36
Ethanol	78.4	6.30
Ammonia	-33.3	4.32
Liquid hydrogen	-252.9	2.54
Compressed H₂ (700 bar)	gas	1.55

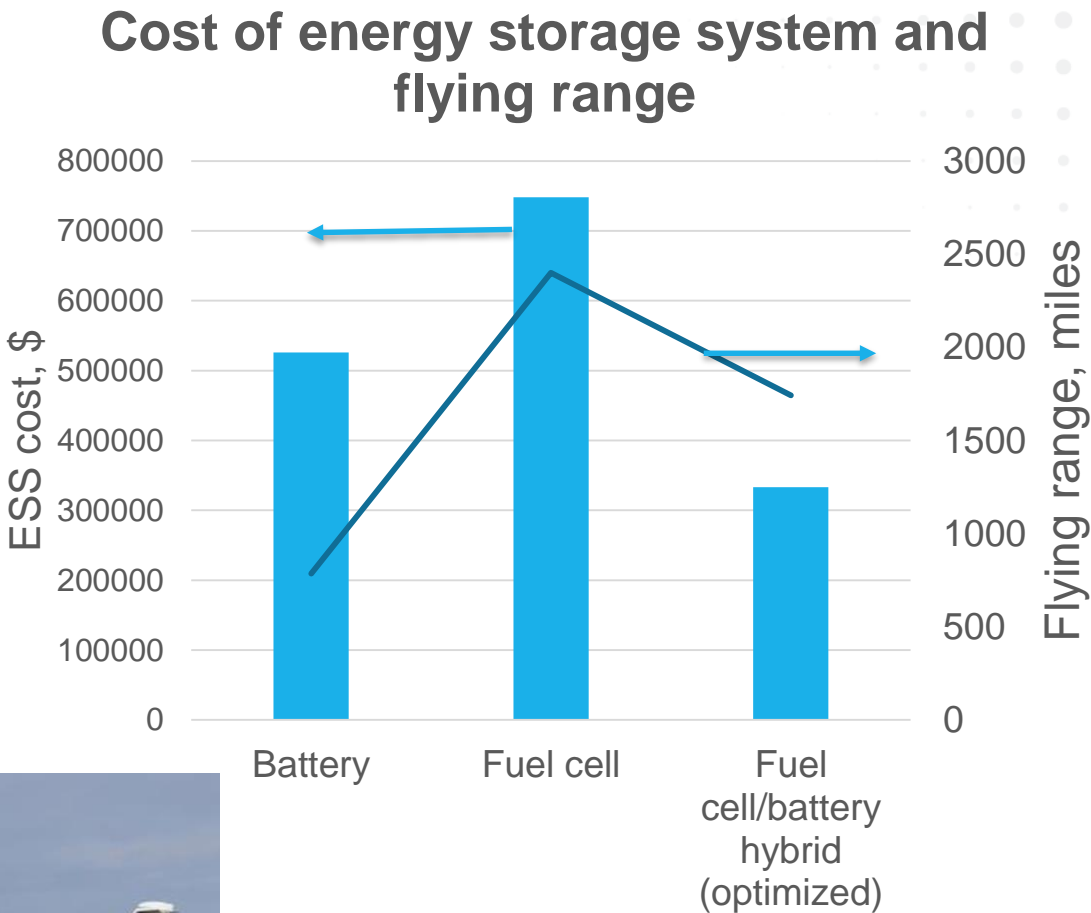


* - Fuel cell efficiency 55%, battery round trip efficiency 90%, energy consumption 4.6 kWh/mile for regional aircraft

Comparison of electric aircraft configurations (ATR72 body)



* - flying range 780 miles



Fuel ethanol, battery cost \$150/kWh, fuel cell cost \$400/kW



Potential Program Requirements: Feedback Sought!

Component Requirements

- Power density comparable with hydrogen fuel cells
- Combining electrocatalysis and fuel reforming catalysis working below 550 C with no coking issues
- Non- or extremely low Pt catalysts adaptable to different liquid fuels

System Requirements

- Specific power > 3 kW/kg
- Start up time less than 15 minutes
- 5,000 thermal cycles with degradation less 5%
- Internal fuel reforming
- Fuel flexibility
- Battery/fuel cell integration

**Q. Electrified future of aviation:
batteries or fuel cells?**

A. Hybrids (batteries + fuel cells)